A PROCESS AND AN APPARATUS FOR PRODUCING METALS AND METAL ALLOYS

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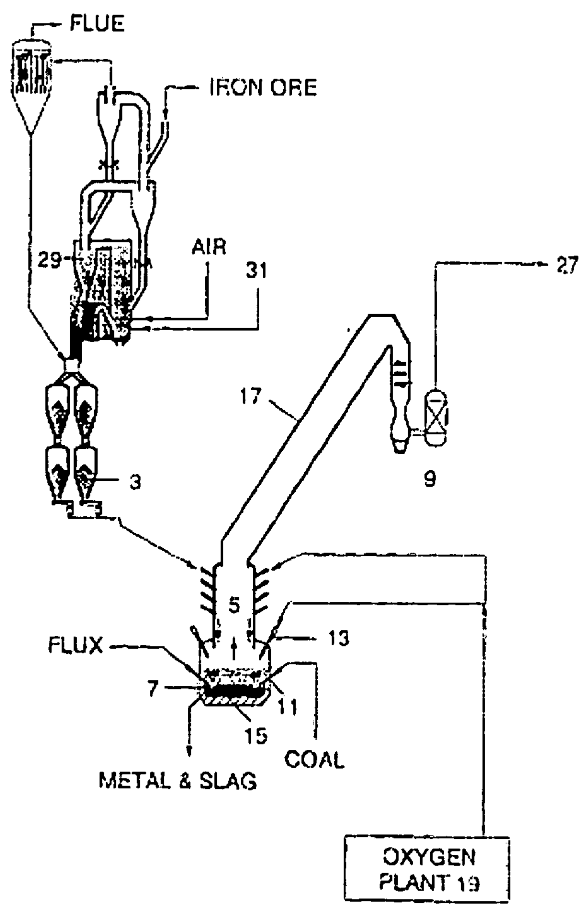
Abstract of **WO0022176**

A process and an apparatus for producing metals from a metalliferous feed material are disclosed. The process includes the steps of partially reducing and at least partially melting a metalliferous feed material in a pre-reduction/melting means and completely reducing the partially reduced feed material in a reduction means. The pre-reduction/melting means is positioned directly above the reduction means and communicates with the reduction means so that at least partially molten, partially reduced feed material flows downwardly into a central region of the reduction means. The reduction means includes a vessel that contains a molten bath having a metal layer and a slag layer on the metal layer. The process includes injecting oxygen-containing gas into the reduction means and post-combusting reaction gas generated in the molten bath and injecting oxygen-containing gas into the pre-reduction/melting means and post-combusting reaction gas discharged from the reduction means. The process further includes injecting solid carbonaceous material and a carrier gas into a metal rich region of the molten bath and causing upward movement of splashes, droplets and streams of molten material which forms a transition zone.



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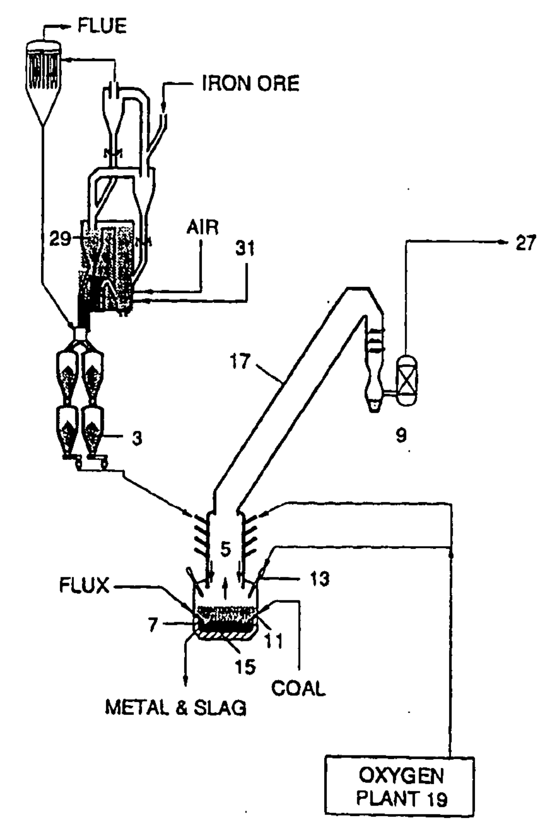
(57) Abstract

A process and an apparatus for producing metals from a metalliferous feed material are disclosed. The process includes the steps of partially reducing and at least partially melting a metalliferous feed material in a pre–reduction/melting means and completely reducing the partially reduced feed material in a reduction means. The pre–reduction/melting means is positioned directly above the reduction means and communicates with the reduction means so that at least partially molten, partially reduced feed material flows downwardly into a central region of the reduction means. The reduction means includes a vessel that contains a molten bath having a metal layer and a slag layer on the metal layer. The process includes injecting oxygen–containing gas into the reduction means and post–combusting reaction gas generated in the molten bath and injecting oxygen–containing gas into the pre–reduction/melting means and post–combusting reaction gas discharged from the reduction means. The process further includes injecting solid carbonaceous material and a carrier gas into a metal rich region of the molten bath and causing upward movement of splashes, droplets and streams of molten material which forms a transition zone.



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A PROCESS AND AN APPARATUS FOR PRODUCING METALS AND METAL ALLOYS

The present invention relates to a process for producing molten metal (which term includes metal alloys), in particular, although by no means exclusively iron, from a metalliferous feed material, such as ores, partly reduced ores and metal-containing waste streams, in a metallurgical vessel containing a molten bath.

The present invention relates particularly to a process and an apparatus for producing molten metal from a metalliferous feed material which is based on the combination of:

(a) a means which partially reduces and at least partially melts the metalliferous feed material; and

(b) a means which completes reduction of the molten partially-reduced feed material.

One example of a pre-reduction/melting means is a cyclone converter.

One example of a reduction means is a vessel that contains a molten bath.

US patent 4,849,015 of Fassbinder et al and US patent 5,800,592 of Den Hartog et al disclose particular proposals for producing molten iron from iron ore using the above combination of pre-reduction/melting means and reduction means.

One object of the present invention is to provide

an alternative process/apparatus for producing molten iron from iron ore which is based on the above combination of pre-reduction/melting means and reduction means.

According to the present invention there is provided a process for producing metals from a metalliferous feed material which includes the steps of partially reducing and at least partially melting the metalliferous feed material in a pre-reduction/melting means and completely reducing the partially reduced feed material in a reduction means, which reduction means includes a vessel that contains a molten bath having a metal layer and a slag layer on the metal layer, and which process is characterised by: -

(a) injecting solid carbonaceous material with a carrier gas into a metal rich region of the molten bath;

(b) causing upward movement of splashes, droplets, and streams of material from the metal layer which:

  (i) promotes mixing of material from the metal layer in the slag layer and mixing of material from the slag layer in the metal layer; and

  (ii) extends into a space above the molten bath to form a transition zone;

(c) injecting an oxygen-containing gas into the vessel and post-combusting part of a reaction gas generated in the molten bath;

(d) transferring at least part of the hot reaction gas from the reduction means to the

pre-reduction/melting means as a reducing gas and partially reducing the metalliferous feed material; and

(e) injecting an oxygen-containing gas into the pre-reduction/melting means and post-combusting a part of the reaction gas and thereby generating heat which at least partially melts the partially-reduced metalliferous feed material.

The term "metal rich region" is understood herein to mean the region (or regions) of the molten bath that has a high concentration of metal. By way of example, the metal layer is one metal rich region.

The term "metal layer" is understood herein to mean that region of the bath that is predominantly metal. Specifically, the term covers a region or zone that includes a dispersion of molten slag in a metal continuous volume.

The term "slag layer" is understood herein to mean that region of the bath that is predominantly slag. Specifically, the term covers a region or zone that includes a dispersion of molten metal in a slag continuous volume.

The term "transition zone" is understood herein to mean a gas continuous volume with splashes, droplets, and streams of molten material (which is at least predominantly slag) therein.

One option for generating the upward movement of splashes, droplets and streams of molten material from the metal layer in step (b) is to inject the solid carbonaceous material and carrier gas in step (b) via one or more than

one lance/tuyere that extend downwards towards the metal layer.

More preferably the one or more than one lance/tuyere extend through side walls of the vessel and are angled inwardly and downwardly towards the metal layer.

It is preferred that the injection of solid carbonaceous material and carrier gas into the metal layer be sufficient to generate upward movement of splashes, droplets and streams of molten material in a fountain-like manner.

The injection of solid carbonaceous material and carrier gas into the metal layer via the downwardly extending lance(s)/tuyere(s) has the following consequences:

(i) the momentum of the solid carbonaceous material/carrier gas causes the solid carbonaceous material and gas to penetrate the metal layer;

(ii) the solid carbonaceous material, typically coal, is devolatilised and thereby produces gas in the metal layer;

(iii) carbon predominantly dissolves into the metal and partially remains as solid;

(iv) the gases transported into the metal layer and generated via devolatilisation produce significant buoyancy uplift of material from the metal layer which results in the above-described upward movement of splashes, droplets and streams of material, and these splashes, droplets, and streams entrain

further slag as they move through the slag layer.

The material referred to in paragraph (d) includes molten metal (which includes dissolved carbon) and molten slag that is drawn into the metal layer from above the metal layer as a consequence of solid/gas injection.

Another option, although by no means not the only other option, to generate the above-described upward movement of splashes, droplets, and streams of material is to inject solid carbonaceous material and carrier gas via one or more than one tuyere in the bottom of the vessel or in side walls of the vessel that contact the metal layer.

Preferably, the pre-reduction/melting means is positioned above the reduction means and communicates with the reduction means so that at least partially molten, partially reduced metalliferous feed material drains downwardly into the reduction means and, more particularly, drains into the vigorously mixed central region of the slag layer in the molten bath. The applicant believes that this leads to more efficient smelting of the pre-reduced material.

Preferably with this arrangement hot reaction gas generated in the reduction means flows upwardly into the pre-reduction/melting means.

As indicated above, the upward movement of splashes, droplets and streams of material from the metal layer promotes mixing of material from the metal layer in the slag layer and mixing of material in the slag layer in the metal layer. Preferably, the extent of mixing is sufficient so that the slag layer is more or less homogeneous in terms of composition and temperature.

The mixing of material between the layers promotes reduction of metal oxides present in the molten bath by dissolved carbon in metal. In this connection the injection of solid carbonaceous material into the metal layer ensures that there are high levels of dissolved carbon (and possibly solid carbon) in the metal layer and that, as a consequence, the metal layer is strongly reducing.

It is preferred that the level of dissolved carbon in metal be greater than 3.5 wt%.

Preferably the process includes the step of preheating the metalliferous feed material before supplying the metalliferous feed material into the pre-reduction/melting means.

Preferably the process includes discharging reaction gas from the pre-reduction/melting means as an off-gas and preheating the metalliferous feed material with the off-gas, either hot or cold.

Preferably steps (c) and (e) of injecting the oxygen-containing gas into the vessel and the pre-reduction/melting means post-combust the reaction gas generated in the molten bath to a post-combustion level of at least 70%.

The term "post-combustion" means:

$$\frac{[CO_2] + [H_2O]}{[CO_2] + [H_2O] + [CO] + [H_2]}$$

where:

$[CO_2]$ = volume % of CO_2 in the reaction gas;
$[H_2O]$ = volume % of H_2O in the reaction gas;

[CO] = volume % of CO in the reaction gas; and
[H_2] = volume % of H_2 in the reaction gas.

More particularly, the term "post-combustion" in the context of post-combustion in the vessel also means post-combustion in the absence of any addition of supplementary carbonaceous material for other purposes.

Preferably injection of oxygen-containing gas into the vessel in step (c) is via one or more than one lance/tuyere that extend downwardly and inwardly into the vessel and are set back sufficiently to be clear of material flowing downwardly from the pre-reduction/melting means into the vessel.

The transition zone is important for three reasons.

Firstly, the ascending and thereafter descending splashes, droplets and streams of material are an effective means of transferring to the molten bath the heat generated by post-combustion of reaction gas in the vessel.

Secondly, the material, and particularly the molten slag, in the transition zone is an effective means of minimising heat loss by radiation via the side walls of the vessel.

Thirdly, dust containing carbon in the transition zone reduces heat loss by radiation to the side walls of the vessel.

Preferably, the vessel includes:

(a) tap holes for discharging molten metal and slag from the vessel; and

(b) one or more than one outlet for transferring reaction gas to the pre-reducing/melting means.

It is preferred that the oxygen-containing gas be oxygen.

According to the present invention there is also provided an apparatus for carrying out the above-described process.

More particularly the present invention provides an apparatus for producing metals from a metalliferous feed material which includes: a pre-reduction/melting means which partially reduces and at least partially melts the metalliferous feed material and a reduction means which completely melts and reduces the at least partially molten and partially reduced feed material; which reduction means includes a vessel that contains a molten bath having a metal layer and a slag layer on the metal layer; which pre-reduction/melting means is positioned directly above the vessel and communicates with the vessel whereby at least partially molten and partially reduced feed material flows downwardly into a central region of the vessel; and which reduction means further includes:

(a) one or more than one lance/tuyere which inject solid carbonaceous material with a carrier gas into a metal rich region of the molten bath;

(b) one or more than one lance/tuyere which inject oxygen-containing gas into the vessel that post-combusts reaction gas generated in the vessel, the one or more than one lance/tuyere extending downwardly and inwardly into the vessel and being

positioned so as to minimise contact with at least partially molten and partially reduced feed material flowing downwardly from the pre-reduction/melting means; and

(c) one or more than one lance/tuyere which inject oxygen-containing gas into the pre-reduction/melting means that post-combusts at least a part of the reaction gas from the vessel.

The present invention is described further by way of example with reference to the accompanying drawings, of which:

Figure 1 is a flowsheet, in largely schematic form, of one preferred embodiment of the process and the apparatus of the present invention; and

Figure 2 is a flowsheet, in largely schematic form, of another preferred embodiment of the process and the apparatus of the present invention.

The following description is in the context of producing molten iron from iron ore and it is understood that the present invention is not limited to this application and is applicable to any suitable metalliferous material.

With reference to Figure 1, iron ore is transferred from a series of storage bins 3 into a pre-reduction/melting means that is in the form of a cyclone converter 5 and is partially reduced (by way of example, up to FeO) and at least partially melted in the cyclone converter 5.

The cyclone converter 5 is positioned directly

above a reduction means that is in the form of:

(a) a metallurgical vessel 7 which contains a molten bath 15 having a metal layer and a slag layer and which has a suitable means (not shown) for tapping molten metal and slag and an outlet for reaction gas that opens directly into the cyclone converter 5; and

(b) lances/tuyeres 11 for injecting solid carbonaceous material and optionally fluxes into the vessel 7 and lances/tuyeres 13 for injecting oxygen into the vessel 7, which lances/tuyeres 11, 13 extend downwardly and inwardly into the vessel through the side wall of the vessel.

A suitable form of the vessel 7 and the lances/tuyeres 11, 13 and a suitable process for reducing metalliferous feed material in the vessel 7 is described in general terms in International applications PCT/AU99/00537 and PCT/AU99/00538 in the name of the applicant. The disclosure in the patent specifications lodged with these patent applications is incorporated by cross-reference.

The process flowsheet of Figure 1 includes injection of solid material and carrier gas into the metal layer 15 via the lances/tuyeres 11. A particular feature of the preferred process flowsheet is that the injected solid material is confined to solid carbonaceous material (typically coal) and optionally one or more than one slag forming agent (typically lime). The gases that are generated by and transported into the metal layer as a consequence of the injection of solid carbonaceous material and carrier gas into the metal layer produce significant buoyancy uplift of molten metal, solid carbon, and molten

slag (drawn into the metal layer as a consequence of solid/gas injection) from the metal layer which generates upward movement of splashes, droplets and streams of molten material and solid carbon, and these splashes, droplets and streams entrain slag as they move through the slag layer.

The buoyancy uplift of molten material and solid carbon causes substantial agitation in the metal layer and the slag layer, with the result that the slag layer expands in volume. The extent of agitation is such that there is strong mixing of material from the metal layer in the slag layer and strong mixing of material from the slag layer in the metal layer.

In addition, the upward movement of splashes, droplets and streams of material caused by the buoyancy uplift of molten metal, solid carbon, and molten slag extends into the gas space above the molten material in the vessel and form a transition zone.

The diameter of the cyclone converter 5 is relatively small compared to that of the vessel 7 and the cyclone converter 5 is positioned centrally above the vessel 7. Accordingly, the at least partially molten, partially-reduced iron ore produced in the cyclone converter 5 flows downwardly into the central region of the molten bath 15 and is completely reduced in the molten bath 15. The mixing of material between the metal layer and the slag layer ensures that complete reduction is achieved effectively and efficiently.

The reactions that occur in the molten bath 15 in the vessel 7 generate reaction gas (such as CO and H_2) and the gas moves upwardly through the vessel 7. Oxygen produced in an oxygen plant 19 is injected into the gas space in the vessel 7 above the molten bath 15 via the lances/tuyeres 13 and post-combusts a part of the reaction

gas in the transition zone and other sections of the gas space. The heat is transferred to the ascending and thereafter descending splashes, droplets and streams of material and the heat is then transferred to the metal layer when the metal/slag returns to the metal layer. In order to avoid damage by contact with material flowing downwardly from the cyclone converter 5, the lances/tuyeres 5 are set back to be clear of such downwardly flowing material.

The post-combusted reaction gas produced in the vessel 7 flows upwardly into the cyclone converter 5 and acts as a reducing gas which partially reduces the iron ore supplied to the cyclone converter 5.

In addition, oxygen produced in the oxygen plant 19 is injected into the cyclone converter 5 and post-combusts at least part of the reaction gas in the cyclone converter 5 and generates heat that melts the partially-reduced iron ore.

The combined level of post-combustion in the vessel 7 and the cyclone converter 5 is at least 70%.

An off-gas discharges from the cyclone converter 5 via a duct 17. The duct 17 includes a water cooling assembly 9 which initially cools the off-gas by means of water panels and thereafter quenches the off-gas and thereby removes entrained solids from the off-gas and reduces the water vapour content of the off-gas.

The quenched off-gas is transferred via a line 27 and is used as a fuel gas or vented flue gas.

The process flowsheet shown in Figure 2 includes all of the components of the flowsheet shown in the figure.

In addition, in the process flowsheet shown in Figure 2 the iron ore is preheated in a preheater assembly 29 prior to supplying the iron ore to the cyclone converter 5. The preheater assembly 29 operates with a part of the fuel gas from the water cooling assembly 9 which is supplied via a line 31. The use of a preheater assembly 29 is an advantage in terms of productivity and operational costs, particularly in situations where the iron ore has high levels of loss of ignition (for example, crystalline water). Moreover, in situations where the iron ore has high levels of loss of ignition, the preheater assembly 29 has the advantage that it minimises thermal decrepitation of iron ore particles when the particles are exposed to high temperatures in the cyclone converter 5.

The Table set out below provides heat and mass balance calculations for the process flowsheets of Figures 1 and 2 under the stated operating conditions.

	Figure 1 flowsheet	Figure 2 flowsheet
Preheater assembly (29)		
Fines Feed	Not applicable	278 tph @ 25C
Pre-reduction/melting means (5)		
Fines Feed	261 tph @ 25C	266 tph @ 700C
Oxygen	37.1 kNm3/h	28.5 kNm3/h
Offgas	252kNm3/h @ 1800C & 77% post combustion	222 kNm3/h @ 1800C & 76% post combustion
Reduction means (7, 11, 13, 15)		
Feed rate	221 tph @ 1600C & 22% pre-reduction	231 tph @ 1600C & 22% Pre-reduction
Oxygen	71.1 kNm3/h	63.0 kNm3/h
Coal	113.0 tph	105.0 tph
Flux	7.1 tph	7.8 tph
Offgas	226 kNm3/h @ 31.5% post combustion	208 kNm3/h @ 34.9% post combustion
Metal	181 tph @ 1500C & 4.0% carbon	188 tph @ 1500C & 4.0% carbon
Slag	21 tph	21 tph
Offgas from Pre-reduction/melting means (5)		
Hood Cooling	132 MW	118 MW
Gas ex Scrubber	211 kNm3/h @ 72% post combustion	88 kNm3/h @ 71% post combustion

The iron ore was sourced from North America and contained 68.2% iron, 0.6% SiO_2 and 0.95% Al_2O_3 on a dry basis.

The coal had a heating value of 33.9MJ/kg, an ash content of 5.4% and a volatiles level of 14%. Other characteristics included 90.0% total carbon, 2.0% H_2O, 1.3% N_2, 3.2% O_2 and 4.0% H_2.

Many modifications may be made to the preferred embodiments of the process and apparatus of the present invention as described above without departing from the spirit and scope of the present invention.

By way of example, the present invention is not limited to the use of cyclone converters and extends to any suitable pre-reduction/melting means.

Furthermore, whilst the above described embodiments include injecting all of the solid carbonaceous material into the metal layers in the vessels 7, it can readily be appreciated that the present invention extends to embodiments in which part of the solid carbonaceous material is top-charged or otherwise supplied to the vessels 7.

Furthermore, whilst the above described embodiments are confined to injecting carrier gas and solid carbonaceous material and optionally slag forming agents into the metal layer via lances/tuyeres 11, it can readily be appreciated that the present invention extends to embodiments in which other solid materials, such as metalliferous feed material, are injected into the metal layers.

CLAIMS:

1. A process for producing metals from a metalliferous feed material which includes the steps of partially reducing and at least partially melting the metalliferous feed material in a pre-reduction/melting means and completely reducing the partially reduced feed material in a reduction means, which pre-reduction/melting means is positioned directly above the reduction means and communicates with the reduction means so that at least partially molten, partially reduced feed material flows downwardly into a central region of the reduction means, which reduction means includes a vessel that contains a molten bath having a metal layer and a slag layer on the metal layer, and which process is characterised by:

(a) injecting solid carbonaceous material with a carrier gas into a metal rich region of the molten bath;

(b) causing upward movement of splashes, droplets, and streams of material from the metal layer which:

(i) promotes mixing of material from the metal layer in the slag layer and mixing of material from the slag layer in the metal layer; and

(ii) extends into a space above the molten bath to form a transition zone;

(c) injecting an oxygen-containing gas into the vessel and post-combusting part of a reaction gas generated in the molten bath;

(d) transferring at least part of the hot

reaction gas from the reduction means to the pre-reduction/melting means as a reducing gas and partially reducing the metalliferous feed material; and

(e) injecting an oxygen-containing gas into the pre-reduction/melting means and post-combusting a part of the reaction gas and thereby generating heat which at least partially melts the partially-reduced metalliferous feed material, whereby steps (c) and (e) post-combust the reaction gas generated in the molten bath to a post-combustion level of at least 70%.

2. The process defined in claim 1 wherein injection of solid carbonaceous material and carrier gas into the metal rich region of the molten bath in step (a) causes upward movement of splashes, droplets, and streams of material from the metal layer in step (b).

3. The process defined in claim 2 wherein injection of solid carbonaceous material and carrier gas is via one or more than one lance/tuyere that extend downwards towards the metal layer.

4. The process defined in claim 2 or claim 3 wherein injection of solid carbonaceous material and gas is via one or more than one tuyere in the bottom of the vessel or in side walls of the vessel that contact the metal layer.

5. The process defined in any one of the preceding claims wherein hot reaction gas generated in the reduction means flows upwardly into the pre-reduction/melting means.

6. The process defined in any one of the preceding claims includes the step of preheating the metalliferous

feed material before supplying the metalliferous feed material into the pre-reduction/melting means.

7. The process defined in claim 6 includes discharging reaction gas from the pre-reduction/melting means as an off-gas and preheating the metalliferous feed material with the off-gas.

8. The process defined in any one of the preceding claims wherein injection of the oxygen-containing gas into the vessel is via one or more than one lance/tuyere that extend downwardly and inwardly into the vessel and are set-back sufficiently to be clear of material flowing downwardly from the pre-reduction/melting means into the vessel.

9. An apparatus for producing metals from a metalliferous feed material which includes: a pre-reduction/melting means which partially reduces and at least partially melts the metalliferous feed material and a reduction means which completely melts and reduces the at least partially molten and partially reduced feed material; which reduction means includes a vessel that contains a molten bath having a metal layer and a slag layer on the metal layer; which pre-reduction/melting means is positioned directly above the vessel and communicates with the vessel whereby at least partially molten and partially reduced feed material flows downwardly into a central region of the vessel; and which reduction means further includes:

(a) one or more than one lance/tuyere which inject solid carbonaceous material with a carrier gas into a metal rich region of the molten bath;

(b) one or more than one lance/tuyere which

inject oxygen-containing gas into the vessel that post-combusts reaction gas generated in the vessel, the one or more than one lance/tuyere extending downwardly and inwardly into the vessel and being positioned so as to minimise contact with at least partially molten and partially reduced feed material flowing downwardly from the pre-reduction/melting means; and

(c) one or more than one lance/tuyere which inject oxygen-containing gas into the pre-reduction/melting means that post-combusts at least a part of the reaction gas from the vessel.

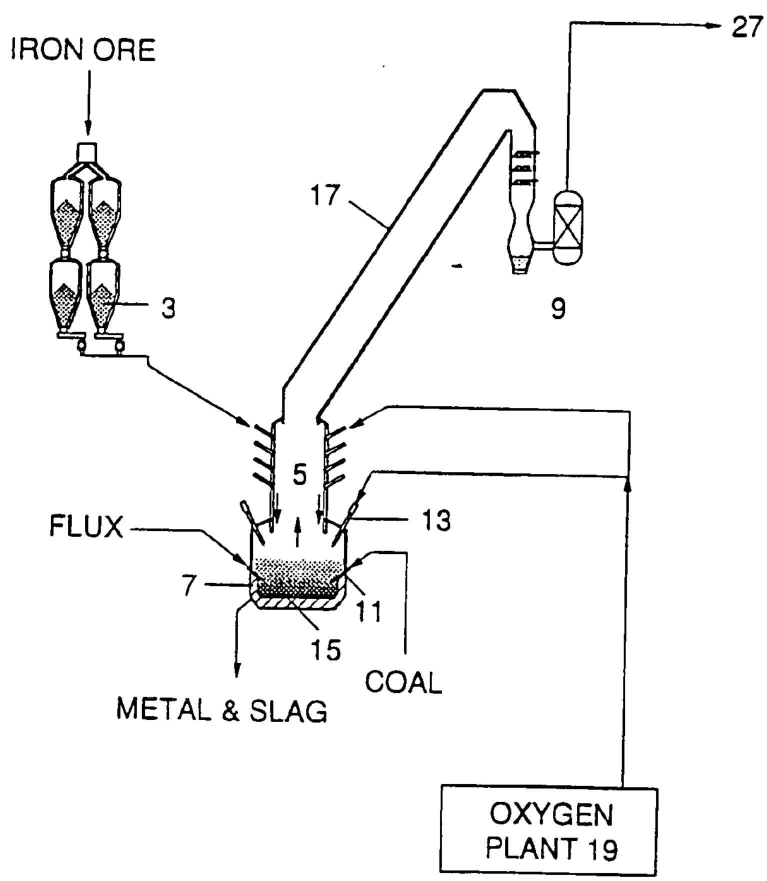
IRON ORE
27
17
3
9
5
FLUX
13
7
11
15
COAL
METAL & SLAG
OXYGEN
PLANT 19

FIGURE 1

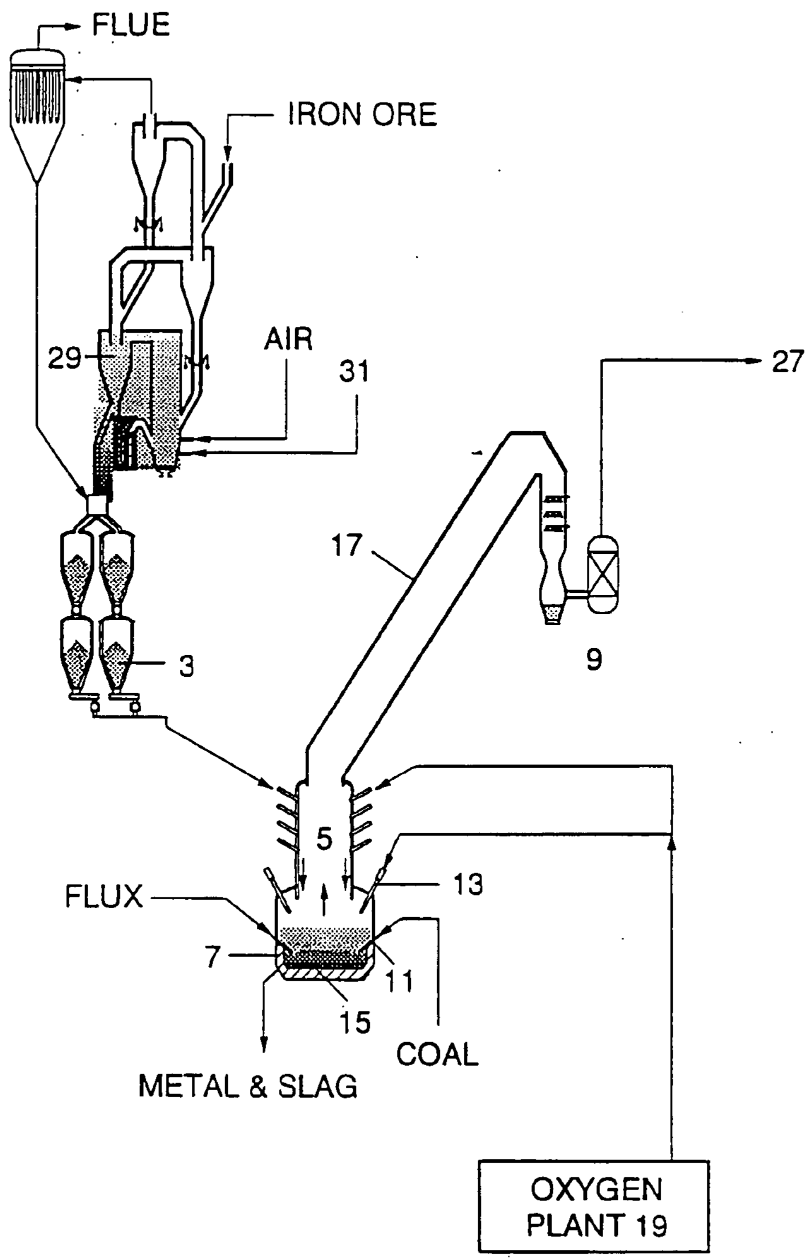
FLUE
IRON ORE
AIR
29
31
27
17
3
9
5
13
FLUX
7
11
15
COAL
METAL & SLAG
OXYGEN
PLANT 19

FIGURE 2

INTERNATIONAL SEARCH REPORT

International application No.
PCT/AU 99/00884

A. CLASSIFICATION OF SUBJECT MATTER

Int Cl^6: C21B 11/00. 11/02; C22B 5/10, 5/12; F27B 19/02, 19/04

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC^6 C21B-; C22B 5/-; F27B 19/-

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
NIL

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
DERWENT ON-LINE WPAT: IPC as above with Keywords post(1) combust:

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X,Y	US 5498277 A (FLOYD et al) 12 March 1996 Column 2 lines 3-20, 34-54; column 3 lines 7-24; column 4, lines 32-47; column 8 lines 12-26; claims 11, 18, 19, 21, 31	1-9
X,Y	WO 96/31627 A1 (TECHNOLOGICAL RESOURCES PTY LTD) 10 October 1996 Whole document	1-9
X,Y	US 5489325 A (KEOGH et al) 6 February 1996 Column 2 lines 16-32; column 3 lines 16-36; column 4 line 62-column 5 line 4; column 5 lines 21-24	1-9

[X] Further documents are listed in the continuation of Box C

[X] See patent family annex

* Special categories of cited documents:

"A" Document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search
11 November 1999

Date of mailing of the international search report
29 NOV 1999

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C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X,Y	US 5050848 A (HARDIE et al) 24 September 1991 Column 1 lines 39-47; column 3 lines 17-26; column 4 line 60-column 5 line 12	1-9
X,Y	US 5640708 A (CONOCHIE et al) 17 June 1997 Column 1 line 57-column 2 line 19; column 3 lines 31-38, 54-59; column 4 lines 23-34; claim 1	1-9
X,Y	US 5480473 A (HARDIE et al) 2 January 1996 Column 3 line 62-column 4 line 43; column 4 line 61-67; claim 1	1-9
X,Y	US 5518523 A (BROTZMANN) 21 May 1996 Column 3 lines 39-67; column 4 line 11-51	1-9
X,Y	WO 98/27232 A1 (TECHNOLOGICAL RESOURCES PTY LTD) 25 June 1998 Page 1 lines 14-35; page 3 lines 26-34; page 4 lines 8-14; page 7 lines 4-14, 27-37; claims 5, 6	1-9
X,Y	US 4861368 A (BROTZMANN et al) 29 August 1989 Column 1 lines 5-11, lines 32-40; column 3 lines 19-27; column 4 lines 34-36; claim 1	1-9
X,Y	WO 98/27239 A1 (TECHNOLOGICAL RESOURCES PTY LTD) 25 June 1998 Page 1 lines 26-34; page 3 line 16-page 4 line 11; page 9 lines 29-35; page 11 line 26-page 12 line 24; claim 10; Figures	1-9
X,Y	US 5401295 A (BROTZMANN) 28 March 1995 Column 3 lines 17-25; column 3 line 56-column 4 line 7; column 4 line 63-column 5 line 6; column 5 line 56-column 6 line 2; column 6 line 60; column 7 line 7; column 8 line 66-column 9 line 10; claims 1, 3; Figures	1-9
Y	US 4566904 A (Von BOGDANDY et al) 28 January 1986 Column 2 lines 5-25; column 4 line 61-column 5 line 7; claims 2, 8	1-9
Y	US 4849015 A (FASSBINDER et al) 18 July 1989 Column 2 line 18-column 3 line 25; column 3 lines 51-59; claims 1, 3	1-9
Y	US 4786321 A (HOSTER et al) 22 November 1988 Column 3 lines 1-27	1-9

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.
PCT/AU 99/00884

This Annex lists the known "A" publication level patent family members relating to the patent documents cited in the above-mentioned international search report. The Australian Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

Patent Document Cited in Search Report		Patent Family Member					
US	5498277	AU	25725/92	BR	9206507	CN	1071957
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		ZA	9207105				
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CONTINUED

INTERNATIONAL SEARCH REPORT

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		DE	3318005	EP	126391	ES	532576
		ES	8502733	JP	59222508	SU	1304749
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END OF ANNEX